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MANACLE BAND RELEASE MECHANISMS

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Presented is the development of several manacle band release mechanisms for sounding rocket payloads, under Contract F19628-81-C-0029. Included are design specifications, separation methods, assembly procedures and applications.

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TABLE OF CONTENTS

ILLUSTRATIONS

1.0 INTRODUCTION

Manacle band release mechanisms have been used successfully in many sounding rocket applications. This report is a study of the basic design and describes modifications to increase the versatility of the manacle band for unique payload requirements. Two of the problem areas specifically addressed are space limitations and sealing of the payload at the separation plane. Separation methods critical to the successful operation of manacle systems are also described.

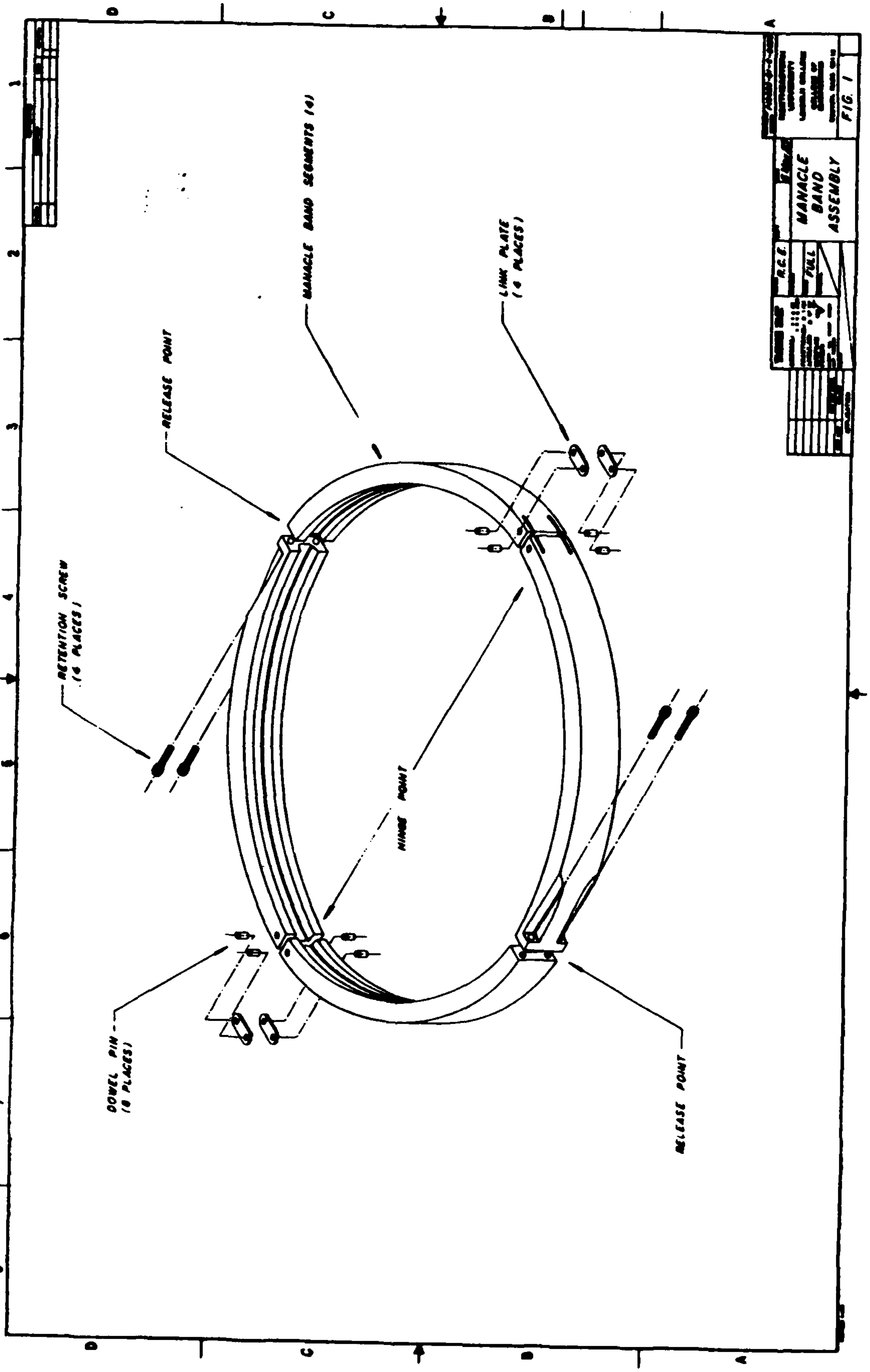
Figure 1, "Manacle Band Assembly" depicts the 4-segment manacle band with dual release and dual hinge points. Cutting either pair of retention screws will release the band and allow separation of the mating cylindrical sections. The referenced contract has adapted manacle bands of this type to 9, 12, 14 and 17.26-inch diameter payloads.

2.0 GENERAL DESIGN

Redundant bolt cutters, actuated by a pyrotechnic pressure cartridge, are used to release the manacle band. All parts of the bolt cutter assembly and the manacle band assembly were studied and tested when applicable to optimize the general design. A 14-inch diameter test fixture was fabricated to accomplish the tests. Keywords: Pyrotechnic pressure

2.1 Bolt Cutter Assembly

The bolt cutter consists of a steel cutting chisel and piston in a flange mounted aluminum housing. Tests of the cutting chisel were conducted to determine a level of hardness that would reliably cut the screws, yet not damage the cutting edge. This allows repeated use of the chisels. The Rockwell "C" scale was used and a hardness level of C51 to C52 was selected.

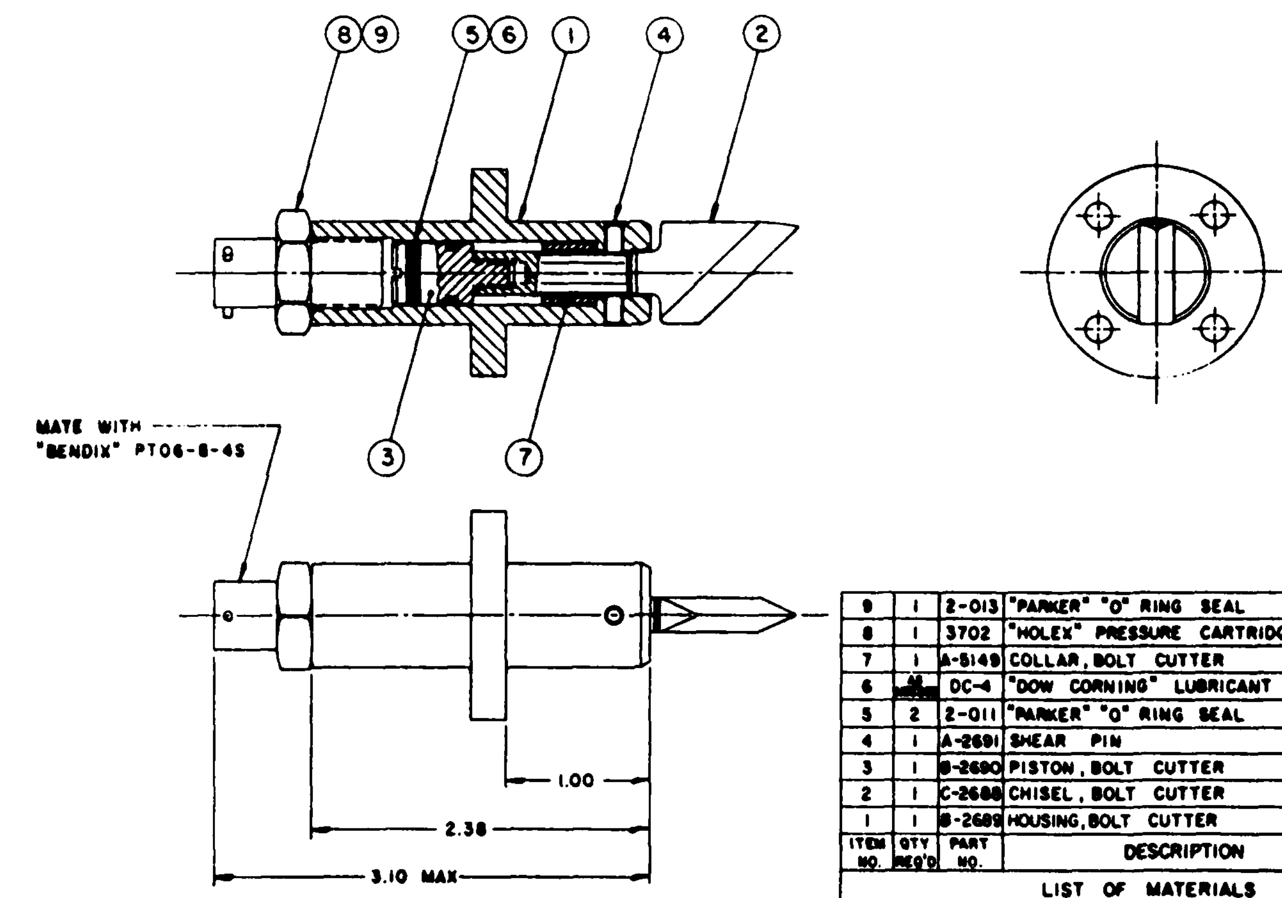

MANACLE BAND SEGMENTS (4)
LINK PLATE (4 PLACES)
RELEASE POINT
RETENTION SCREW (4 PLACES)
HINGE POINT
DOWEL PIN (8 PLACES)
RELEASE POINT
MANACLE BAND ASSEMBLY
FULL
FIG. 1

Another problem encountered during tests was that the cutting chisel was breaking free of the housing after cutting the retention screws. Initially modifications were made to the impact collar (Item 7, Figure 2) in an attempt to retain the chisel. The length and wall thickness of the collar were varied during tests and several different materials were used. A .38-inch dia. x .50 long copper sleeve with a .03-inch wall thickness was most effective, but did not eliminate the chisel retention problem completely. Indications were that the pressure cartridge was providing too much energy to the modified bolt cutter assembly. Pressure cartridges with an energy output of 115 ft.-lbs. (Holex Incorporated Part No. 3702) had been used in all mechanisms to date. Additional tests were conducted using alternate pressure cartridges. Reducing the energy output by approximately 25% (Holex Part No. 3703, energy output of 87 ft.-lbs.) proved effective in reliably operating the mechanisms, yet retaining the chisel. Test results are reported in Section 6.2.

2.2 Manacle Band Assembly

A typical manacle band assembly and list of materials is shown in Figure 3. The manacle band is fabricated from 7075-T6 aluminum and has a 15^{o} V-groove surface which interlocks with the appropriately machined separation rings on the mating payload sections. The band is machined as one continuous ring and cut into four segments which are marked in order to maintain their relationship for final assembly. Chromic acid anodize plating is used on the segments to provide a smooth finish.

Manacle band cross-section, retention screws, link plates and dowel pin requirements were reviewed. Load test data in Section 6.3 was performed on a 14-inch diameter payload section with a manacle band cross-section of 1 1/8" x 1/4", #6-32 UNC x 7/8 inch long black oxide steel



ITEM NO.	QTY REQ'D	PART NO.	DESCRIPTION	MATERIAL
9	1	2-013	"PARKER" "O" RING SEAL	BUNA N
8	1	3702	"HOLEX" PRESSURE CARTRIDGE	—
7	1	A-5149	COLLAR, BOLT CUTTER	—
6	[illegible]	DC-4	"DOW CORNING" LUBRICANT	—
5	2	2-011	"PARKER" "O" RING SEAL	BUNA N
4	1	A-2691	SHEAR PIN	ALUMINUM
3	1	B-2690	PISTON, BOLT CUTTER	STEEL
2	1	C-2688	CHISEL, BOLT CUTTER	STEEL
1	1	B-2689	HOUSING, BOLT CUTTER	ALUMINUM

LIST OF MATERIALS

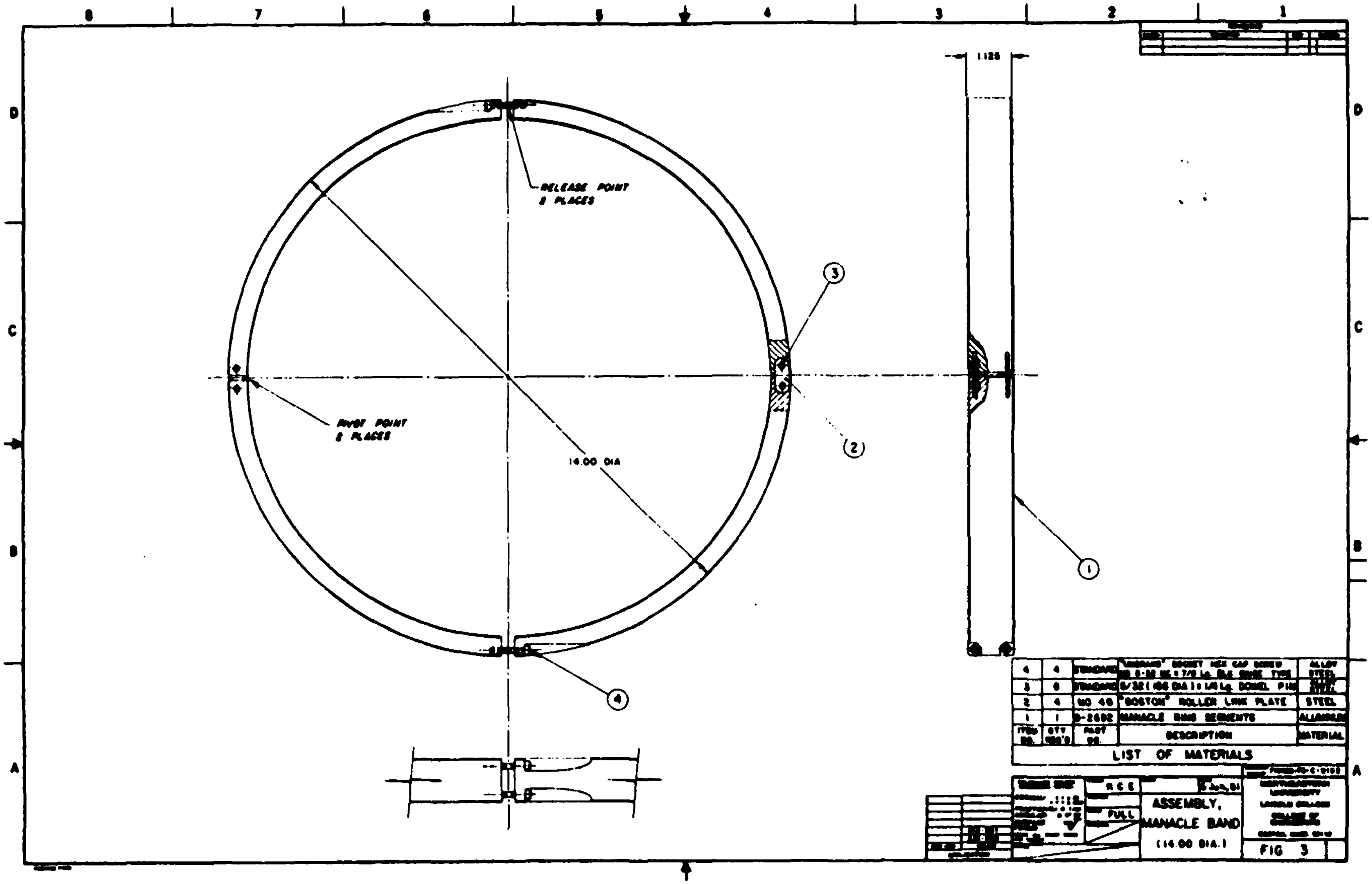
R.C.E. 3 Oct. 80

2X

ASSEMBLY, BOLT CUTTER

NORTHEASTERN UNIVERSITY
LINCOLN COLLEGE
COLLEGE OF ENGINEERING
BOSTON, MASS. 02115

FIG. 2



1.125
RELEASE POINT
2 PLACES
PIVOT POINT
2 PLACES
14.00 DIA
"BOSTON" ROLLER LINK PLATE
NO 40
STEEL
MANACLE RING SEGMENTS
DESCRIPTION
MATERIAL
LIST OF MATERIALS
R C E
FULL
ASSEMBLY,
MANACLE BAND
(14.00 DIA.)
FIG 3

retention screws, 5/32" steel dowel pins, and steel link plates that were double the thickness of previous designs.

3.0 SEPARATION METHODS

Significant to the use of manacle band release mechanisms is a means of providing the required separation force. Spring force has been used successfully; however, available space on the separation plane limits the size and quantity of springs that can be used to attain the required separation velocity. Another consideration is the necessity of preloading the springs in order to assemble the mating payload rings and then the manacle band. Also, the separation velocity requirements must be defined during the design phase in order to incorporate the spring separation system.

Alternatives to springs include a gas generated system or an air bag. The gas system consists of a refillable gas bottle, explosive valve and a manifold to distribute the gas to piston thrusters which impart the separation force. This system has an advantage of being inert at assembly and allowing the separation force to be varied by selecting different gas tank pressures. On the negative side, the system requires significantly more payload space than its spring counterpart and adds payload weight. Similarly, the air bag system is inert at assembly, provides a variable separation force; but requires most of the cylindrical area in the separation plane for the annular ring.

A list of separation methods used to date are included in Table 1. As indicated, gas piston and several spring configurations were used to meet the requirements of a variety of applications and payload diameters.

PAYLOAD NUMBER	DIAMETER (INCHES)	LOCATION	SEPARATION METHOD
A13.030	14	NOSECONE	10 SPRINGS
		AFT/BOOSTER	GAS PISTON
A13.031	14	NOSECONE	14 SPRINGS
		AFT/BOOSTER	GAS PISTON
A19.250	17.26	NOSECONE	8 SPRINGS
A20.123	9	NOSECONE	4 SPRINGS
A21.426	12	AFT/BOOSTER	GAS PISTON

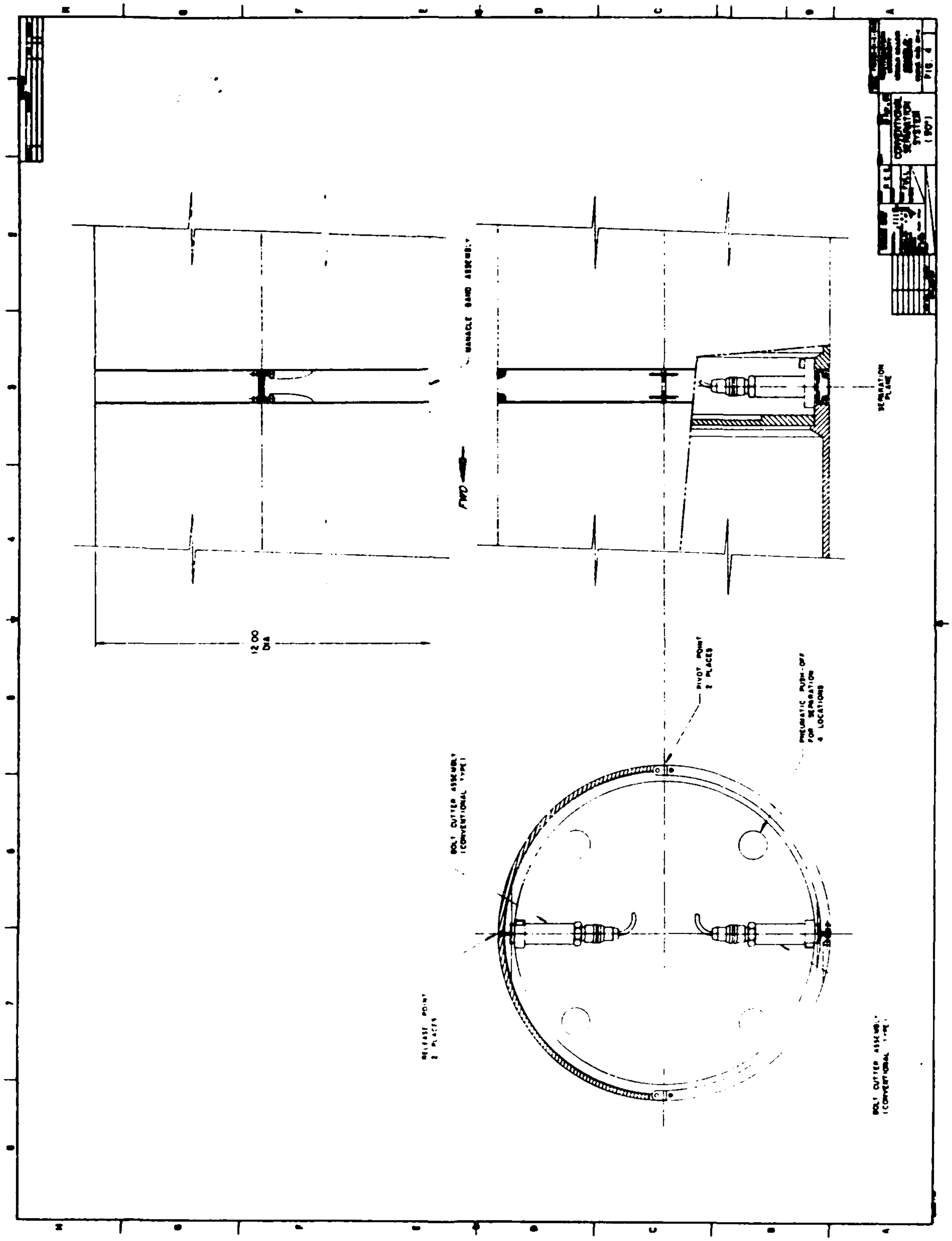
TABLE 1

4.0 90^{0} MANACLE BAND SEPARATION SYSTEM

A conventional 90^{0} manacle band separation system is shown in Figure 4 on a 12-inch diameter payload. This concept allows a relatively simple machining process for the mating ring and requires no special feed-through provision for the electrical power connectors which can be mated directly to the pressure cartridge at assembly. As indicated in Figure 4, the redundant bolt cutter assemblies in this configuration require a significant amount of the available area, precluding their use on smaller diameter payloads. Also, forward or aft looking instruments are frequently mounted at the separation plane. The 90^{0} separation system significantly reduces the available instrument area.

5.0 OFFSET SEPARATION SYSTEM

To increase usable payload area in the separation plane the dual bolt cutter assemblies can be mounted at an angle. This alternative


MANACLE BAND ASSEMBLY
FWD
SEPARATION PLANE
12.00 DIA
PIVOT POINT 2 PLACES
PNEUMATIC PUSH-OFF FOR SEPARATION 4 LOCATIONS
BOLT CUTTER ASSEMBLY (CONVENTIONAL TYPE)
RELEASE POINT 2 PLACES
BOLT CUTTER ASSEMBLY (CONVENTIONAL TYPE)
CONVENTIONAL SEPARATION SYSTEM (90°)
FIG. 4

also allows use in smaller diameter payloads. A 45° offset system was incorporated in AFGL payloads A20.123-1 and A20.123-2 for nosecone ejection. A forward looking mass spectrometer was at the separation plane of these 9-inch diameter payloads.

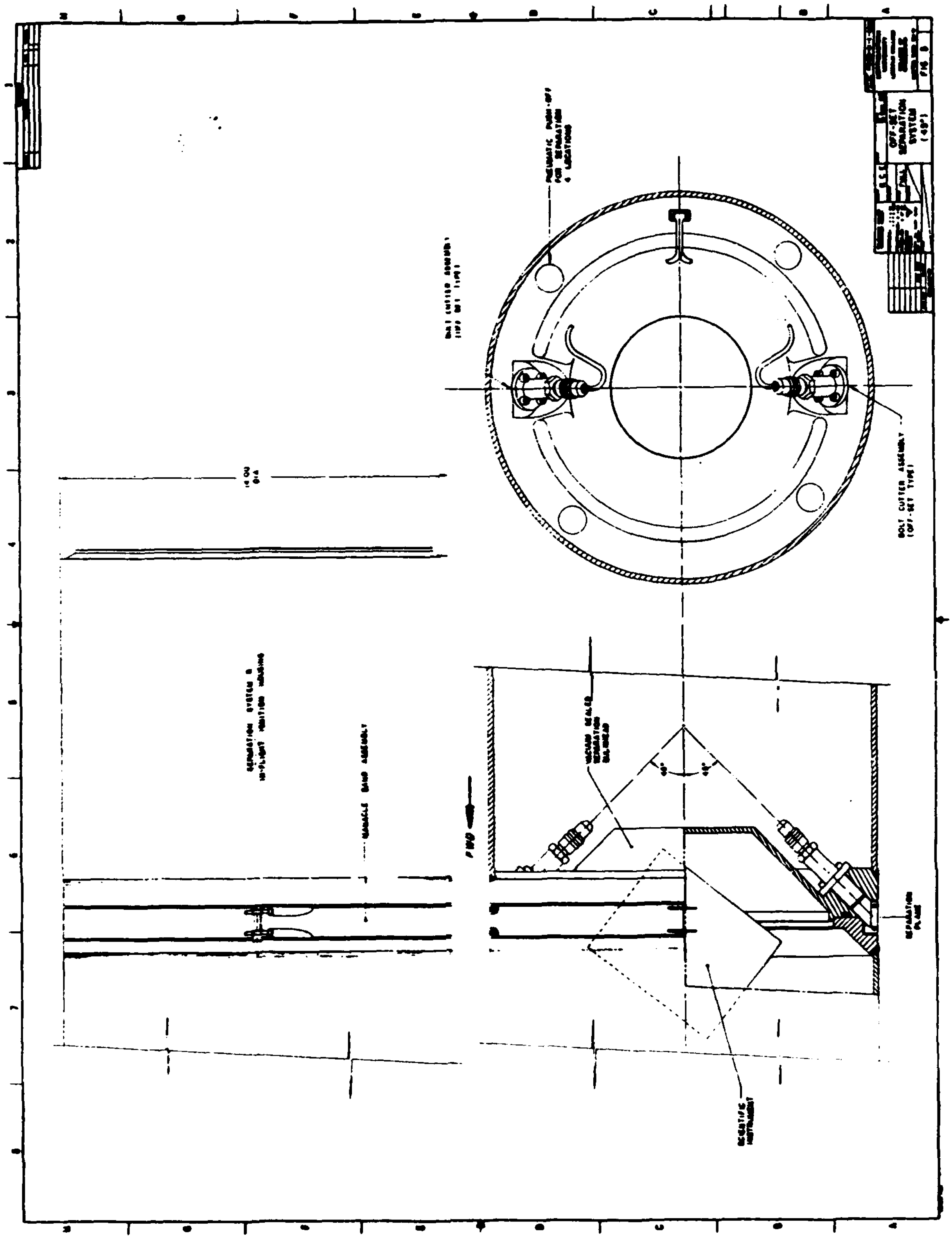
Another advantage of the offset configuration is that it enables sealing of the separation bulkhead. Many payload sections require either a vacuum environment or a controlled positive pressure during boost for instrument operation. One application is depicted in Figure 5 for a 14-inch diameter payload utilizing bolt cutters at 45°. The payload section is sealed with a O-ring and the bulkhead geometry allows the instrument to protrude forward of the separation plane. A gas generated system with four pneumatic thrusters provides the separation force for this system which was implemented on the two 14-inch diameter payloads and later modified for use on a 12-inch diameter. An important consideration of this design is that the pneumatic thruster contact points are located outside the O-ring to maintain the integrety of the seal. A disadvantage of the system compared to the 90° manacle separation is a complex machining process.

6.0 ASSEMBLY AND TESTING

Assembly of the bolt cutter and manacle band as-well-as structural integrity of the V-band are critical to the successful operation of the separation system. The following sections summarize the procedures and tests conducted.

6.1 Assembly Procedures

Bolt cutter assembly refers to materials listed in Figure 2. The bolt cutter chisel (Item 2) will require reaming of clearance holes and


OFF-SET SEPARATION SYSTEM (45°)
BOLT CUTTER ASSEMBLY (OFF-SET TYPE)
FWD
SEPARATION PLANE
SCIENTIFIC INSTRUMENT

re-tapping due to the residue from the hardening process. The chisel is then inserted into the housing (Item 1) and the shear pin (Item 4) and collar (Item 7) are installed. Two O-rings (Item 5) are lubricated and placed on the piston which is in turn inserted into the housing. Caution is advised in not damaging the O-rings on the threaded area of the housing while installing the piston. Finally, the pressure cartridge (Item 8) and its O-rings (Item 9) are threaded into the housing and torqued to a maximum of five-foot-pounds.

The first step in manacle band assembly is to install the four link plates and 8 dowel pins at the pivot points. After insuring that the pivot points are moving freely, the dowel pins are staked flush with the mounting surfaces. The mating surfaces are then sprayed with a dry lubricant, such as Teflon, and the manacle band is placed in poition. Insure that the gap at each release point is equal and centered on the bolt cutter chisel before inserting the 4, #6-32 retention screws. Several torquing steps are required to insure that the manacle band is seated properly. Each time the screws are torqued, a soft-faced hammer is used to tap the band starting at the pivot points and moving toward the release points. A final torque of 25 to 30-inch-pounds is required.

6.2 Separation Tests

The first manacle band design was fired in the test fixture five times actuating both pressure cartridges. Since this is a redundant system, four additional tests were conducted by deliberately firing only one of the pressure cartridges. All tests were successful. In addition, the seven systems described in Section 7.0 were all successfully test fired during payload integration and functioned flawlessly in flight.

6.3 Bend Tests

Bend tests were conducted on a 14-inch diameter payload test fixture to determine compliance of the manacle band joint. The payload was assembled in a cantilever position, oriented with the retention screws positioned vertically, and a series of loads were applied. Between each test the system was disassembled and the manacle band was reset, cleaned and re-torqued.

A maximum moment of 143,000-inch pounds in a downward direction was achieved in the first test with no apparent slippage of the joint. Constraints in the test set-up limited the reverse loading to 96,500-inch-pounds. Two additional tests were conducted with moments of 144,200-inch-pounds downward and 146,500-inch-pounds in the upward direction. These tests indicated the manacle band joint exceeded the flight requirements for the 14-inch diameter payload on a Taurus-Orion launch vehicle.

The manacle band joint was then taken to destruction, in the same orientation, to determine maximum load capacity. At a moment of 350,897-inch-pounds the band broke away and the payload dropped from the fixture. Inspection revealed that the #6-32 retention screws had failed in tension; however, the manacle band was not damaged.

7.0 APPLICATIONS

The first application of the modified manacle band separation system was a 14-inch diameter payload with the following requirements:

- Forward looking instruments at and above the nosecone separation plane.
- Aft looking instruments at and above the vehicle separation plane.
- Provisions for evacuating and purging of both instrument sections, requiring sealing at the separation plane.
- Increase cross-section of manacle band to meet launch vehicle specifications for the aft joint.

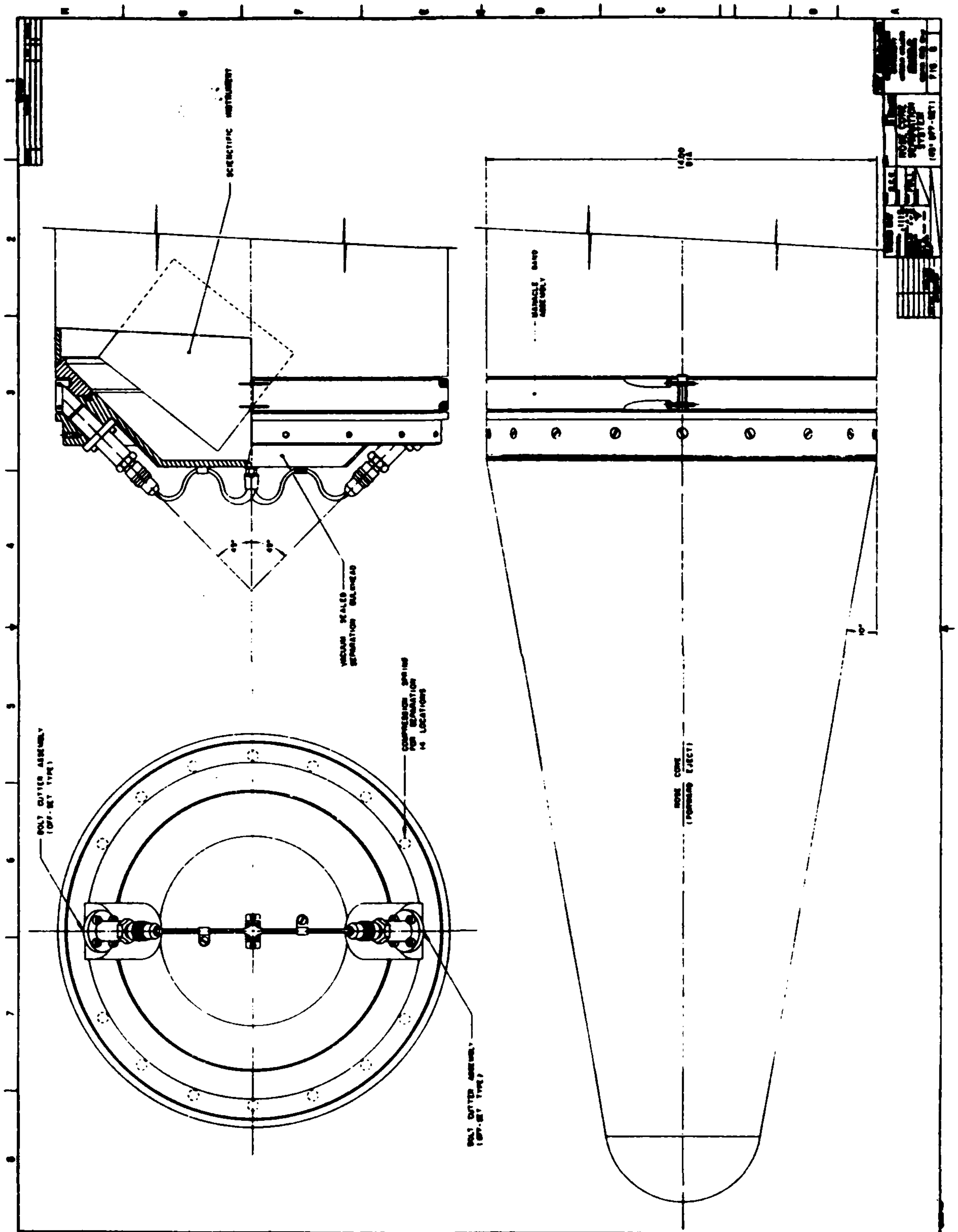
Figure 6 illustrates the manacle band separation system used to forward eject the 10^{0} nosecone. As indicated 45^{0} offset, redundant bolt cutters were used and the rectangular shaped instrument (electron spectrometer) was mounted at the required angle above the vacuum sealed separation bulkhead. The 45^{0} offset separation system described in Section 5.0, with a similar instrument configuration, was used at the aft sealed separation plane.

Modifications were then made to accommodate a forward looking mass spectrometer in a 9-inch diameter payload. This required pulling off the mass spectrometer cap, but not sealing of the separation plane. The 45^{0} offset system was implemented, eliminating the sealed bulkhead and providing a cap-pull mechanism with the nosecone release. These and subsequent applications are summarized in the following table.

PAYLOAD NUMBER	DIAMETER (INCHES)	LOCATION	BULKHEAD CONFIGURATION	CUTTER ORIENTATION
A13.030	14	NOSECONE	SEALED	45^{0}
		AFT/BOOSTER	SEALED	45^{0}
A13.031	14	NOSECONE	SEALED	45^{0}
		AFT/BOOSTER	SEALED	45^{0}
A19.250	17.26	NOSECONE	OPEN	90^{0}
A20.123	9	NOSECONE	OPEN	45^{0}
A21.426	12	AFT/BOOSTER	SEALED	45^{0}

TABLE 2

A total of 28 test firings have been successfully completed to date and all six manacle band systems functioned normally during the launch of payloads A13.030, A13.031, A20.123 and A21.426. Payload A19.250 is scheduled for launch in June 1985.


SCIENTIFIC INSTRUMENT
VACUUM SEALED SEPARATION BULKHEAD
BOLT CUTTER ASSEMBLY (OFF-SET TYPE)
BOLT CUTTER ASSEMBLY (OFF-SET TYPE)
NOSE CONE (FORWARD EJECT)

APPENDIX A

Related Contracts and Reports

Contract No. AF19628-81-C-0029 15 February 1981 to present.

R.L. Morin and C.B. Sweeney, "Model 2480 Timer", Scientific Report No. 1, AFGL-TR-85-0112, November 1982.

APPENDIX B

Personnel

The following members of the Electronics Research Laboratory staff contributed to the work reported.

Lawrence J. O'Connor	Principal Investigator
Richard L. Morin	Research Associate, Engineer
Robert D. Anderson	Mechanical Designer
Roger C. Eng	Mechanical Designer
Joseph R. Colleran	Project Assistant